Resolving the Cassini/Huygens Relay Radio Anomaly

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NASA's Cassini spacecraft is currently about three years away from beginning its primary mission exploring the Saturnian system. It carries ESA's Huygens probe, which it will release shortly before an encounter with Saturn's moon, Titan. Huygens is equipped with a suite of instruments for studying the atmosphere and surface of Titan, which is a possible location for extraterrestrial life within our Solar System. Huygens has no propulsion system and will therefore have a ballistic trajectory toward Titan. At various times during the descent, Huygens will deploy a series of parachutes and eject an aeroshell. It will then acquire scientific information as it drifts toward the surface. If it survives on the surface (if indeed there is a hard surface!) it will continue to acquire information. The information gathered by Huygens will be relayed to Earth through a special dedicated radio on Cassini. This relay link will begin just after the aeroshell is ejected and end when Cassini passes Titan and loses sight of Huygens. The duration of the link is expected to be approximately three hours, depending on various error sources including the direction and magnitude of Titan's wind. Comprehensive testing of this relay radio link was not performed prior to Cassini launch. Since Huygens cannot send radio signals to Cassini while it is bolted to the side of the mother craft, there is now no way to test the link using Huygens. Fortunately, ESA designed a test that used NASA's Deep Space Network (DSN) to mimic the probe's signal from Earth, including signal strength and Doppler. Unfortunately, this test uncovered an anomaly that, unchecked, would result in nearly complete loss of the Huygens mission. The relay radio was not capable of tracking the expected Doppler profile of the Huygens radio signal during its descent through Titan's atmosphere. Sadly, the relay radio had been designed so that it cannot be reconfigured in flight. An international team of experts from NASA and ESA was assembled to resolve this anomaly: the Huygens Recovery Task Force (HRTF.) This team performed extensive ground and flight-testing, modeling, and simulation to understand the failure mechanism in the relay radio. Each subsystem in the relay link was analyzed, modeled, and the results verified by a testing campaign. Tests were performed using a complete engineering model of the relay radio system at ESOC as well as additional in-flight tests using the DSN. The models were used to predict the corruption of science data under various scenarios. These predictions were given to each Huygens science team to determine mission impacts for the various scenarios. This led to a suggested modification to the Cassini trajectory that will result in complete data return for Huygens while having minimal impact on the Cassini orbital mission. This paper describes the anomaly, the testing process, the failure mechanism, and the proposed new mission design for Huygens.